(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 482 943 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **91309885.1**

(22) Date of filing: **25.10.91**

(51) Int. Cl.^{5}: **H04B 10/24,** H04J 14/02

(30) Priority: **26.10.90 JP 290527/90**
29.08.91 JP 218766/91

(43) Date of publication of application:
29.04.92 Bulletin 92/18

(84) Designated Contracting States:
DE FR GB NL

(71) Applicant: **NEC CORPORATION**
7-1, Shiba 5-chome Minato-ku
Tokyo 108-01 (JP)

(72) Inventor: **Suzuki, Syuji**
c/o NEC Corporation, 7-1, Shiba 5-chome
Minato-ku, Tokyo (JP)

(74) Representative: **Orchard, Oliver John**
JOHN ORCHARD & CO. Staple Inn Buildings
North High Holborn
London WC1V 7PZ (GB)

(54) Bidirectional optical transmission method and apparatus therefor.

(57) A method and an apparatus for bidirectional optical transmission capable of communicating in the bidirection through a single optical transmission path are disclosed. A light traveling in one direction is modulated by a first base band signal and another light traveling in another direction is modulated by a subcarrier signal which is modulated by a second base band signal for subsequent conversion into the binary digit pulse. A light receiving circuit for receiving the light traveling in said another direction is comprised of a synchronizing detection demodulator and at least a light receiver to which an electrical signal synchronizing to the subcarrier signal is applied.

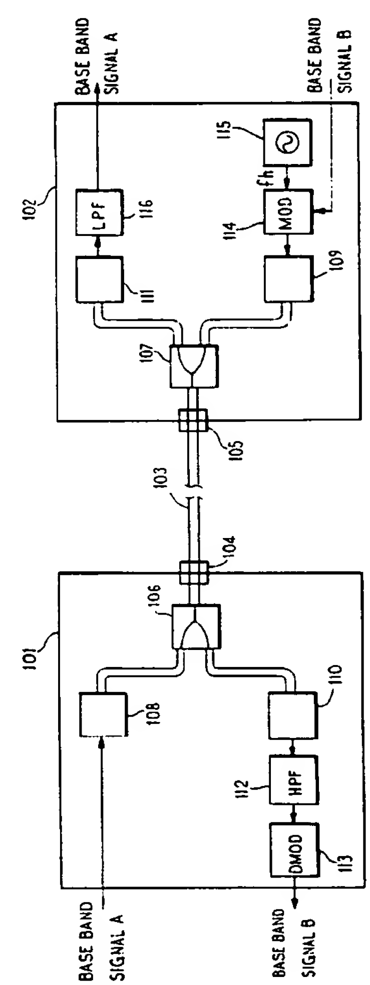


FIG.3

EP 0 482 943 A2

BACKGROUND OF THE INVENTION

The present invention relates to a bidirectional optical transmission method and apparatus therefor using a single optical transmission path.

As a conventional method for bidirectional optical transmission of signals between two stations through an optical transmission path such as an optical fiber and the like, there is a wavelength-division multiplexed (WDM) bidirectional optical transmissions method as described in IEEE, Journal of Lightwave Technology, Vol.7, No. 11, page 1733 to 1740.

An apparatus according to the conventional method of the WDM bidirectional optical transmission is shown in Fig. 1 of the accompanying drawings. In Fig. 1, a base band signal A inputted into an optical transmitting/receiving unit 401 is converted into a light signal of wavelength λ_1 at a light source 408, and fed out to an optical transmission path 403 through a wavelength multiplexer/demultiplexer (WMUX/DEMUX) 406 and an optical connector 404. The light signal of wavelength λ_1 inputted into an optical transmitting/receiving unit 402 through an optical connector 405 is supplied to a light receiver 411 through an WMUX/DEMUX 407 and is converted into an electrical signal. On the other hand, the base band signal B inputted into the optical transmitting/receiving unit 402 is converted into a light signal of wavelength λ_2 at a light source 409, and is fed to the optical transmission path 403 through the WMUX/DEMUX 407 and the optical connector 405. The light signal of wavelength λ_2 inputted into the optical transmitting/ receiving unit 401 from the optical connector 404 is supplied to a light receiver 410 through the WMUX/DEMUX 406, and is converted into the electrical signal.

When the light signal of wavelength λ_1 from the light source 408 passes through the optical connectors 404 and 405, a part of the light signal is reflected. Since the reflected light signal has wavelength of λ_1, the signal returns only to the light source 408 by means of the WMUX/DEMUX 406. Accordingly, the light receiver 410 is prevented from interference due to the reflected light. Similarly, a part of the light signal of wavelength λ_2 from the light source 409 is reflected when the signal passes through the optical connectors 405 and 404, and the reflected signal returns only to the light source 409 by means of the WMUX/DEMUX 407. Accordingly, the light receiver 411 is also prevented from interference due to the reflected light.

For another bidirectional optical transmission method, a multi-subcarrier bidirectional optical transmission method is described in IEEE, Journal of Lightwave Technology, vol. 7, No. 11, pages 1819 to 1824. An apparatus according to the conventional method of multi-subcarrier bidirectional optical transmission is shown in Fig. 2. In Fig. 2, a base band signal A inputted into an optical transmitting/receiving unit 501 is introduced to a modulator 517. The modulator 517 frequency-modulates an output signal (a subcarrier signal) of frequency $f_ℓ$ of the subcarrier oscillator 516 depending on the base band signal A. The subcarrier signal which is frequency-modulated by the base band signal A is converted into a light signal at a light source 508, and is fed out to an optical transmission path 503 through an optical coupler 506 and an optical connector 504. The light signal inputted into the optical transmitting/receiving unit 502 from an optical connector 505 is supplied on a light receiver 511 through an optical coupler 507, and is converted into an electrical signal. The electrical signal is inputted into a demodulator 519 through a low-pass filter 518 whose cut-off frequency is set tc be slightly higher than frequency $f_ℓ$ of the subcarrier oscillator 516, thus the base band signal A is demodulated.

On the other hand, the base band signal B inputted into the optical transmitting/receiving unit 502 is introduced to a modulator 514. The modulator 514 freguency-modulates an output signal (a subcarrier signal) of frequency f_h of a subcarrier oscillator 515 depending on the base band signal B. Now assume that the frequency f_h is higher than $f_ℓ$. The subcarrier signal frequency-modulated by the base band signal B is converted into a light signal at a light source 509, and is fed out to the optical transmission path 503 through the optical coupler 507 and optical connector 505. The light signal inputted into the optical transmitting/receiving unit 501 from the optical connector 504 is supplied to a light receiver 510 through the optical coupler 506, and is converted into an electrical signal. The electrical signal is inputted into a demodulator 513 through a high-pass filter 512 whose cut-off frequency is set to be slightly lower than freguency f_h of the subcarrier oscillator 515, thus the base band signal B is demodulated.

When the light signal from the light source 508 passes through the optical connectors 504 and 505, a part of the light signal reflects, and returns to the light receiver 510 through the optical coupler 506. Accordingly, the output of the light receiver 510 is comprised of the subcarrier signal frequency-modulated of frequency- f_h intrinsically to be received and the other subcarrier signal frequency-modulated of frequency $f_ℓ$ that is an interfering wave due to reflection. But the interfering wave is removed by the high-pass filter 512. Similarly, when the light signal from the light source 509 passes through the optical connectors 504 and 505, a part of the light signal reflects and returns to the light receiver 511 through the optical coupler 507. Accordingly, the output of the light receiver 511 is comprised of the subcarrier signal frequency-modulated of frequency $f_ℓ$ intrinsically to be received and the other subcarrier signal frequency-modulated of frequency f_h that is the interfering wave due to reflection. But the interfering wave is removed by the low-pass filter 518.

However, in the apparatuses of the conventional methods of the bidirectional optical transmission as hereinbefore described, wavelengths of the opposed light sources are set to be different from each other free of interference communication due to reflection of light through the use of the WMUX/DEMUX, and thus problems exist in its higher cost of the transmission apparatus necessitated of the expensive WMUX/DEMUX and of two sets of modulators and demodulators for the subcarrier signals.

SUMMARY OF THE INVENTION

The bidirectional optical transmission method according to the present invention, the lights are allowed to bidirectionally travel on a single optical transmission path to carry out bidirectional communications by first and second base band signals, wherein the light traveling in one direction is modulated by the first base band signal and another light traveling in another direction is modulated by a subcarrier signal which is modulated by the second base band signal.

Further, the subcarrier signal is modulated by the second base band signal for subsequent conversion into the binary digit pulse which modulates the light.

The bidirectional optical transmission apparatus according to the invention, the light receiving circuit for receiving the light traveling in another direction is comprised of a light receiver and a synchronizing detection demodulator.

More further, the light receiving circuit includes at least a light receiver to which an electrical signal synchronizing to the subcarrier signal is applied.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention with be described more in detail with reference to the accompanying drawings:

Figs. 1 and 2 are pictorical views showing conventional apparatuses of bidirectional optical transmissions;

Fig. 3 is a pictorical view showing the first embodiment of a bidirectional optical transmission apparatus according to the present invention;

Fig. 4 is a spectrum diagram of electrical signals of the embodiment in Fig. 3;

Fig. 5 is a pictorical view showing the second embodiment of a bidirectional optical transmission apparatus according to the invention;

Fig. 6 is a pictorical view showing the third embodiment of apparatus of the bidirectional optical transmission according to the invention;

Fig. 7 is a block diagram showing an embodiment of the synchronising detection demodulator in Fig. 6;

Fig, 8 is a spectrum diagram of electrical signals of Fig. 7; and

Fig. 9 is a pictorical view showing a fourth embodiment of apparatus of the bidirectional optical transmission according to the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

In Fig. 3, the bidirectional optical transmission apparatus for the base band signals A and B with the binary digit is shown. The base band signal A inputted into an optical transmitting/receiving unit 101 is converted into a light signal at a light source 108 and is fed out to an optical transmission path 103 through an optical coupler 106 and an optical connector 104. The light signal inputted to an optical transmitting/receiving unit 102 from an optical connector 105 is supplied to a light receiver 111 through an optical coupler 107 and is converted into an electrical signal. The electrical signal passes through a low-pass filter 116 and is fed out as a received base band signal A. On the other hand, the base band signal B inputted into the optical transmitting/receiving unit 102 is introduced to a modulator 114. The modulator 114 modulates an output signal (a subcarrier signal) of frequency f_h of the subcarrier oscillator 115 depending on the base band signal B. For modulation type in this case, for example, a frequency modulation could be employed, and if the base band signal is a binary digit signal of 1.5 Mb/bs, f_h may be in the extent of 6 MHz. The subcarrier signal frequency-modulated by the base band signal B is converted into the light signal at a light source 109 and is fed out to the optical transmission path 103 through the optical coupler 107 and the optical connector 105. The light signal inputted into the optical transmitting/receiving unit 101 from the optical connector 104 is supplied to the light receiver 110 through the optical coupler 106 and is converted into an electrical signal. The electrical signal is inputted to the demodulator 113 through the high-pass filter 112 and the base band signal B is demodulated.

In Fig. 4, a spectrum 201 is for the base band signal A, and it is distributed in the frequencies equal to or less than frequency f_A. A spectrum 202 expresses a subcarrier signal or an output of the modulator 114, and is distributed in the range of frequencies form $f_h - f_B$ to $f_h + f_B$ centering around frequency f_h. The spectrums 201

and 202 are not overlapped each other.

In Fig. 3, when the light signal from the light source 108 passes through the optical connectors 104 and 105, a part of the light signal reflects and returns to the light receiver 110 through the optical coupler 106. Accordingly, an output of the light receiver 110 includes the subcarrier signal intrinsically to be received and with the spectrum 202 and the interfering signal produced by reflection and with the spectrum 201. However, the spectrums 201 and 201 are not overlapped each other, thus the interfering signal with the spectrum 201 is removed by the high-pass filter 112 whose cut-off frequency is set intermediate between f_A and $f_h - f_B$. On the other hand, when the light signal from the light source 109 passes through the optical connectors 105 and 104, a part of the light signal reflects and returns to the light receiver 111 through the optical coupler 107. Accordingly, an output of the light receiver 111 includes the base band signal A intrinsically to be received and with the spectrum 201 and the interfering signal produced by reflection and with the spectrum 202. Also in this case, the interfering signal with the spectrum 202 is removed by a low-pass filter 116 whose cut-off frequency is set intermediate between f_A and $f_h - f_B$.

Fig. 5 shows the second embodiment of the invention in which is added to the first embodiment a pulse producing device. The embodiment is provided with a pulse producing device 301 between the modulator 114 and the light source 109. By means of the pulse producing device 301, the output subcarrier signal of the modulator 114 is converted into binary digit and thereafter inputted into the light source 109. Accordingly the light source 109 is not necessary to have a high grade of linear characteristic. In this case, the spectrum of output signal of the pulse producing device 301 becomes to include high-frequency with several times in the integer number the spectrum 202 in Fig. 4. These frequencies only include higher frequency components than the spectrum 202, and are not laminated with the spectrum 201. Thus even in the embodiment in Fig. 5, the interfering signal produced by reflection is eliminated by the high-pass filter 112 and the low-pass filter 116.

The embodiments hereinbefore described employ a frequency modulation system for the subcarrier modulation system, however, an amplitude modulation, a pulse modulation, and the like could also be employed. For the base band signal, there could be used not only binary digit signals but also analog signals or the signals n or above ternary digit. A relationship between the frequency band of the base band signal and the frequency f_h of the subcarrier signal could be set optionally if the spectrums 201 and 202 are not laminated as shown in Fig. 4.

In Fig. 6, as compared with the embodiment shown in Fig. 3, a synchronising detection demodulator 601 is employed as the demodulator 113, so that the high-pass filter 112 could thus be omitted with lower cost for the transmitting apparatus.

Fig. 7 shows an example of the synchronizing detection demodulator 601. In Fig. 7, a bi-phase modulated signal to be demodulated is inputted to a multiplier 701, and is multiplied by the signal frequency-divided by two of an output of a voltage control oscillator 707. On the other band, a low-pass filter 705 passes only low-frequency components of the extent of the frequency band of the base band signal B from among the output signals of the multiplier 701, thus its output signal is satisfied by the following formula,

$$\frac{A1 \cdot A2}{2} \sin(-\Delta\theta \pm 90°) = \pm \frac{A1 \cdot A2}{2} \cos \Delta\theta$$

where the demodulation is carried out for a base band signal B whose amplitude is varied of positive or negative depending on phase variation of ±90° of the bi-phase modulated signal. The signal is inputted to a multiplier 703, accordingly an output signal of the multiplier 703 is expressed as the following formula,

$$\frac{A1 \cdot A2 \cdot A3}{8} \Big[-\frac{1}{2} \sin(\Delta\theta \pm 180°) + \sin(-\Delta\theta \pm 90°) \Big\{ \cos(4\pi f_h + \Delta\theta \pm 90°) - \cos(4\pi f_h - \Delta\theta \pm 90°) - \cos(8\pi f_h + \Delta\theta \pm 90°) \Big\} \Big]$$

when a low-frequency component approximating direct-current of the output signal is taken out by a low-pass filter 706, the following formula is established,

$$- \frac{A1 \cdot A2 \cdot A3}{16} \sin(\Delta\theta \pm 180°)$$

$$= \frac{A1 \cdot A2 \cdot A3}{16} \sin \Delta\theta$$

where is obtained the signal proportional to a phase difference $\Delta\theta$. Accordingly, with this value inputted to a voltage control oscillator 707, the automatic control is performed to make $\Delta\theta$ zero.

Figs. 8(a) and 8(b) are diagrams illustrative of spectrums of input and output signals to the multiplier 701 within the synchronizing detection demodulator shown in Fig. 7. Fig. 8(a) illustrates spectrums of the input signal of the multiplier 701, which spectrums are comprised of a spectrum 801 of the signal in which the subcarrier of frequency f_h is bi-phase modulated by the base band signal B and another spectrum 802 of the base band signal A of the interfering signal produced by reflection. In the output of the multiplier 701 shown in Fig. 8(b), the multiplying causes frequency conversion, the spectrum 801 is converted into two spectrums, a spectrum 805 of a base band signal B and a spectrum 803 of a center frequency $2f_h'$. On the other hand, the spectrum 802 is converted into a spectrum 804 of a center frequency f'. Accordingly, if only the spectrum 805 is allowed to pass at the low-pass filter 705 in Fig. 7, the base band signal B is could be obtained free of the interfering signal. In this way, the construction in Fig. 6 could prevent the interfering signal without providing a high-pass filter in the previous stage of the synchronizing detection demodulator 601.

Fig. 9 is a diagram illustrative of a fourth embodiment of the invention. A signal from a 1/2 frequency divider 704 is applied to the light receiver 901 within the present optical transmitting/receiving unit 101. When an AC signal is applied to the light receiver employing a photo-diode or a photo-conductor, the operation is provided for multiplying the opto-electronic converter signal by the AC signal. Accordingly the light receiver 901 could operate as the light receiver and the multiplier using only one element, there could thus be obtained a cost reduction corresponding to one multiplier to be reduced.

As hereinbefore fully described, according to the present invention, the bidirectional optical transmissions could be carried out with the apparatus in lower cost since the interfering signals produced by reflection could be removed through the use of only one set of subcarrier modulator and demodulator free of the expensive light have combining/splitting unit.

Claims

1. A bidirectional optical transmission system in which lights are allowed to bidirectionally travel on a single optical transmission path to carry out bidirectional communications by first and second base band signals, wherein a light traveling in one direction is modulated by the first base band signal and another light traveling in another direction is modulated by a subcarrier signal which is modulated by the second base band signal.

2. A bidirectional optical transmission system as claimed in claim 1, wherein the subcarrier signal is modulated by the second base band signal for subsequent conversion into the binary digit pulse which modulates the light.

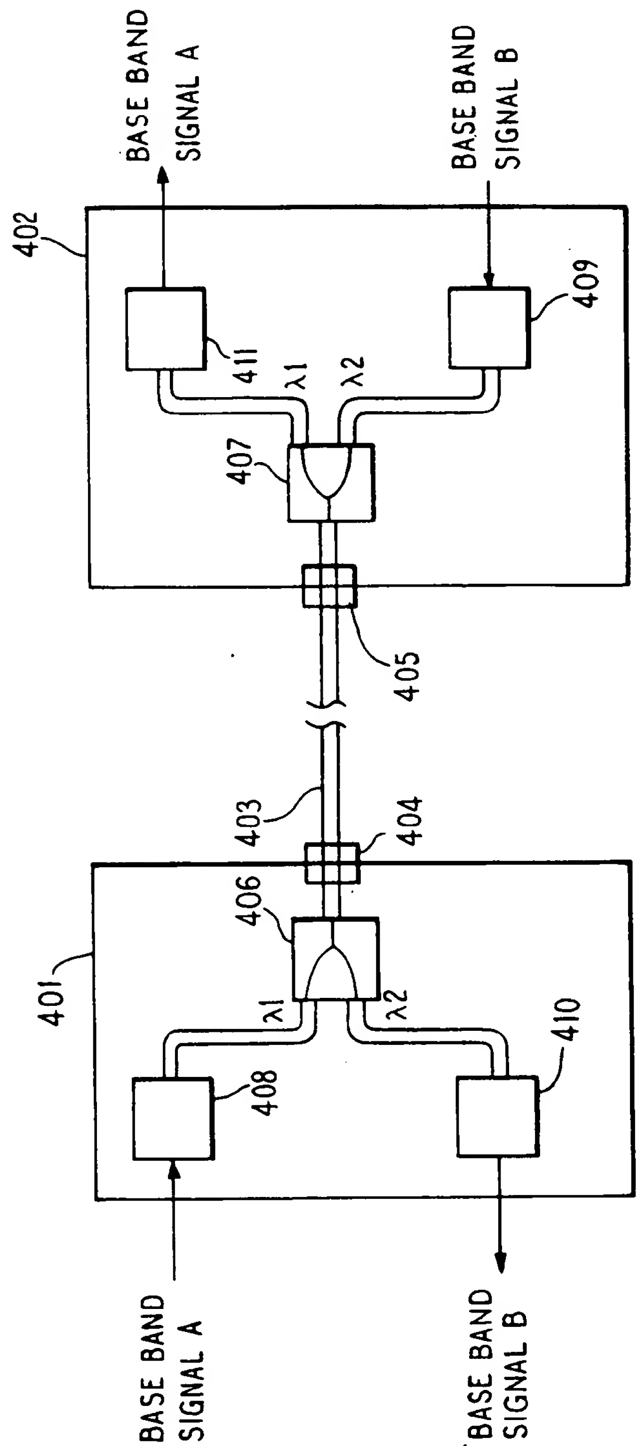
3. A bidirectional optical transmission apparatus in which lights are allowed to bidirectionally travel on a single optical transmission path to carry out bidirectional communications by first and second base band signals, wherein a light traveling in one direction is modulated by the first base band signal and another light traveling in another direction is modulated by a subcarrier signal which is modulated by the second base band signal, and a light receiving circuit for receiving the light traveling in said another direction is comprised of a light receiver and a synchronizing detection demodulator.

4. A bidirectional optical transmission apparatus as claimed in claim 3, in which lights are allowed to bidirectionally travel on a single optical transmission path to carry out bidirectional communications by first and second base band signals, wherein a light traveling in one direction is modulated by the first base band signal and another light traveling in another direction is modulated by a subcarrier signal which is modulated by the second base band signal, and a light receiving circuit for receiving the light traveling in said

another direction includes at least a light receiver to which an electrical signal synchronizing to the subcarrier signal is applied.

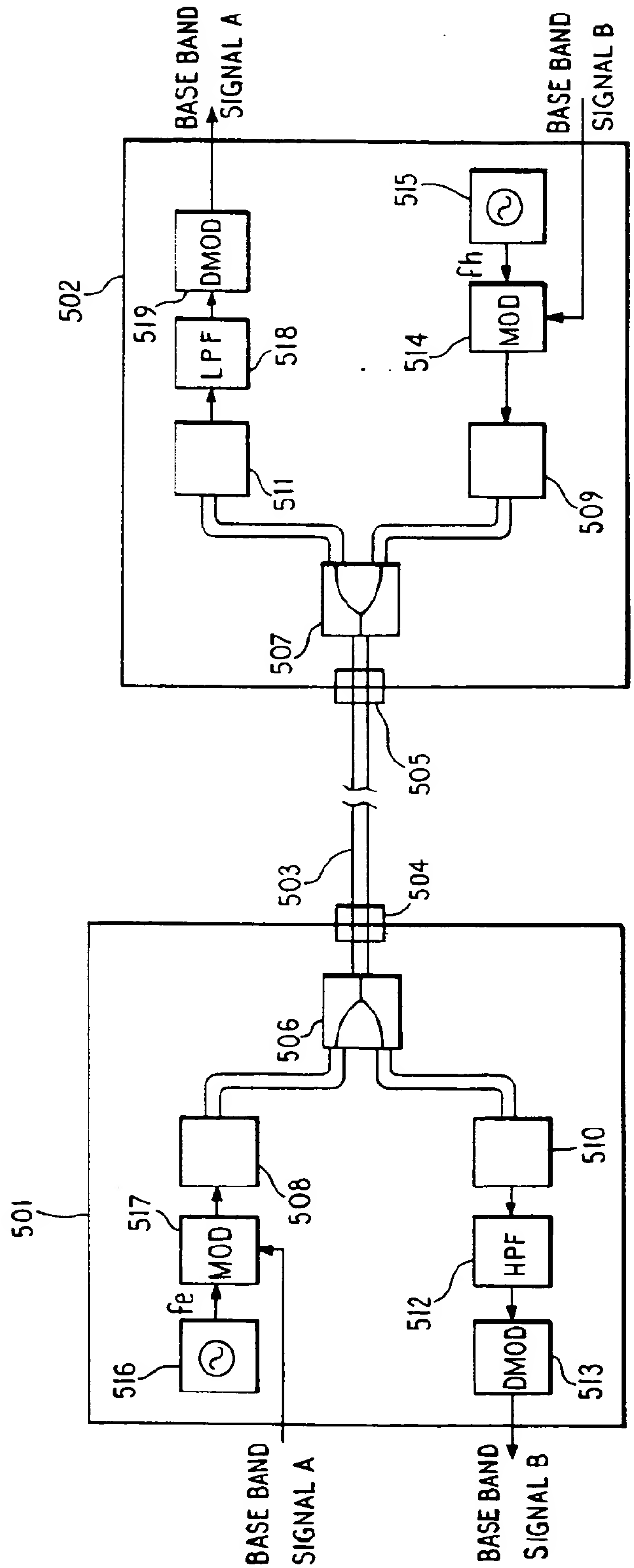
5. A method for bidirectional transmission of a first and a second base band signal using single optical path comprising the steps of:
   (a) modulating a first optical signal by said first base band signal;
   (b) transmitting said first optical signal to said optical path as a transmission signal in one direction of said bidirection;
   (c) modulating a subcarrier signal whose frequency is higher than said first baseband signal by said second base band signal;
   (d) modulating a second optical signal by said modulated subcarrier signal; and
   (e) transmitting said second optical signal to said optical path as a transmission signal for the other direction of said bidirection.

FIG. 1



PRIOR ART

FIG.2



PRIOR ART

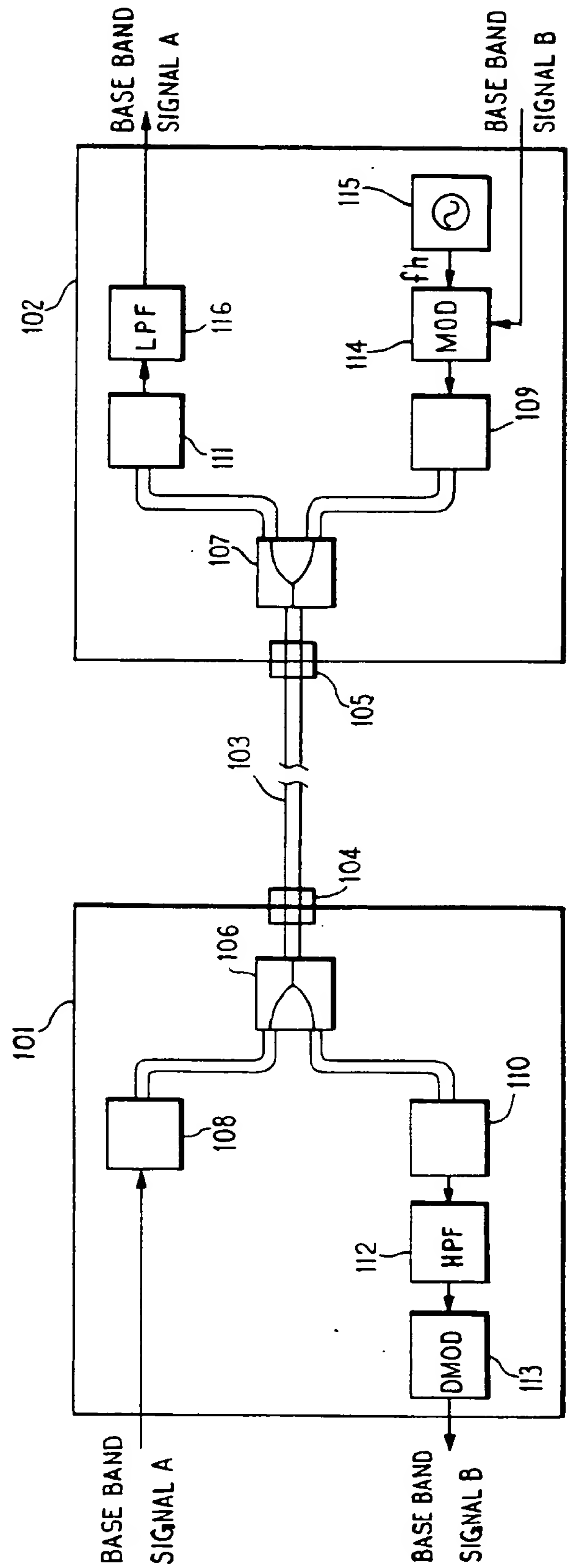

BASE BAND
SIGNAL A
BASE BAND
SIGNAL B
102
LPF
116
115
fh
MOD
114
111
109
107
105
103
104
106
101
108
110
HPF
112
DMOD
113
BASE BAND
SIGNAL A
BASE BAND
SIGNAL B

FIG. 3

FIG.4

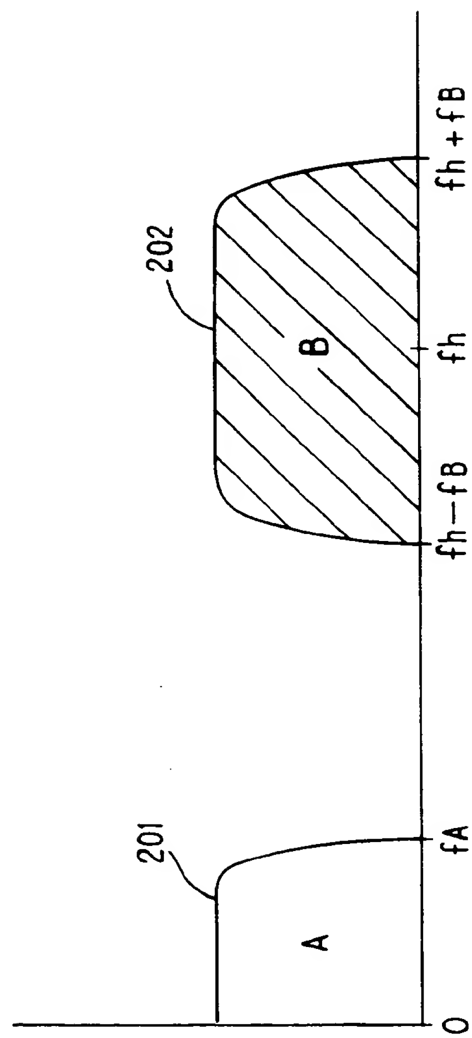


FIG.5

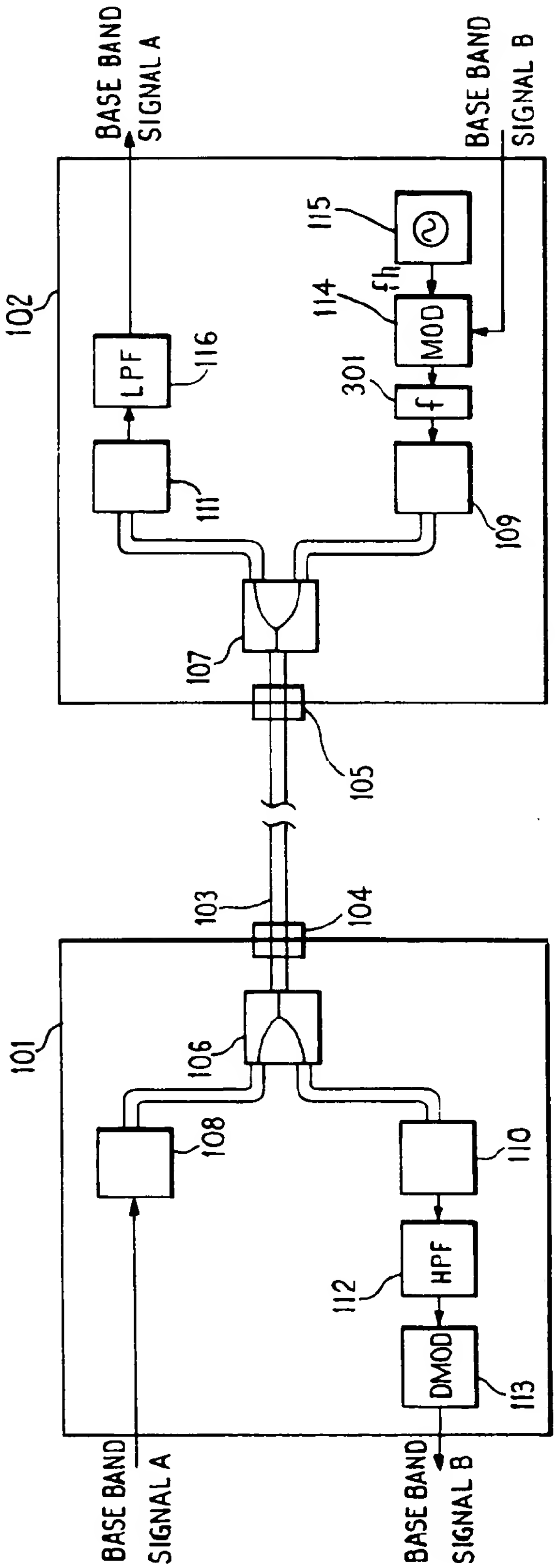

BASE BAND SIGNAL A
BASE BAND SIGNAL B
102
LPF
116
111
109
107
105
MOD
114
115
fh
f
301
103
104
101
106
108
110
HPF
112
DMOD
113
BASE BAND SIGNAL A
BASE BAND SIGNAL B

FIG. 6

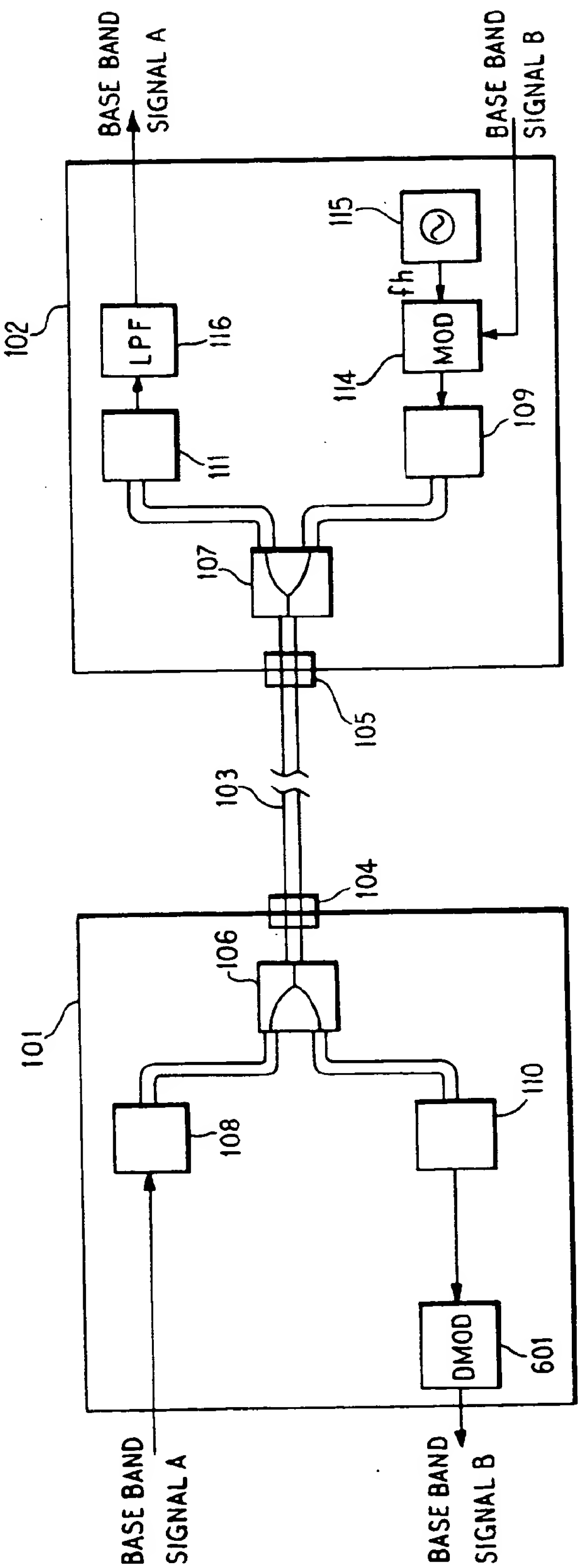
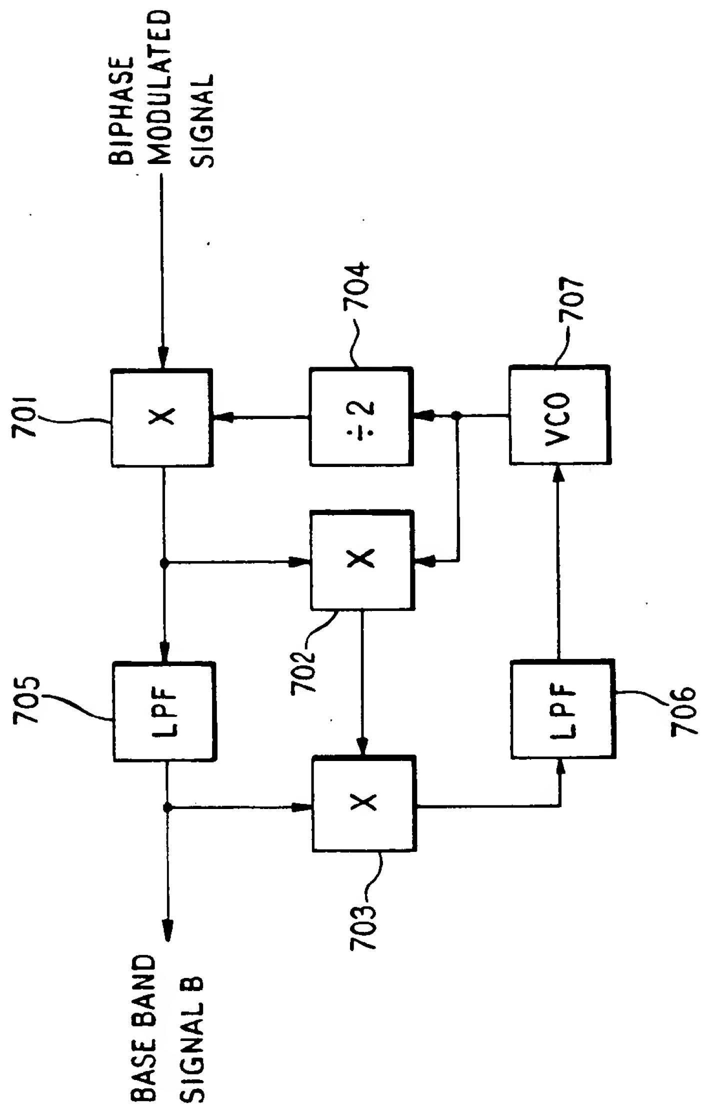

BASE BAND SIGNAL A
SIGNAL A
BASE BAND SIGNAL B
SIGNAL B
102
LPF
116
115
fh
MOD
114
109
111
107
105
103
104
106
101
108
110
DMOD
601
BASE BAND
SIGNAL A
BASE BAND
SIGNAL B

FIG.7


BIPHASE MODULATED SIGNAL
701
X
÷2
704
VCO
707
X
702
LPF
705
X
703
LPF
706
BASE BAND SIGNAL B

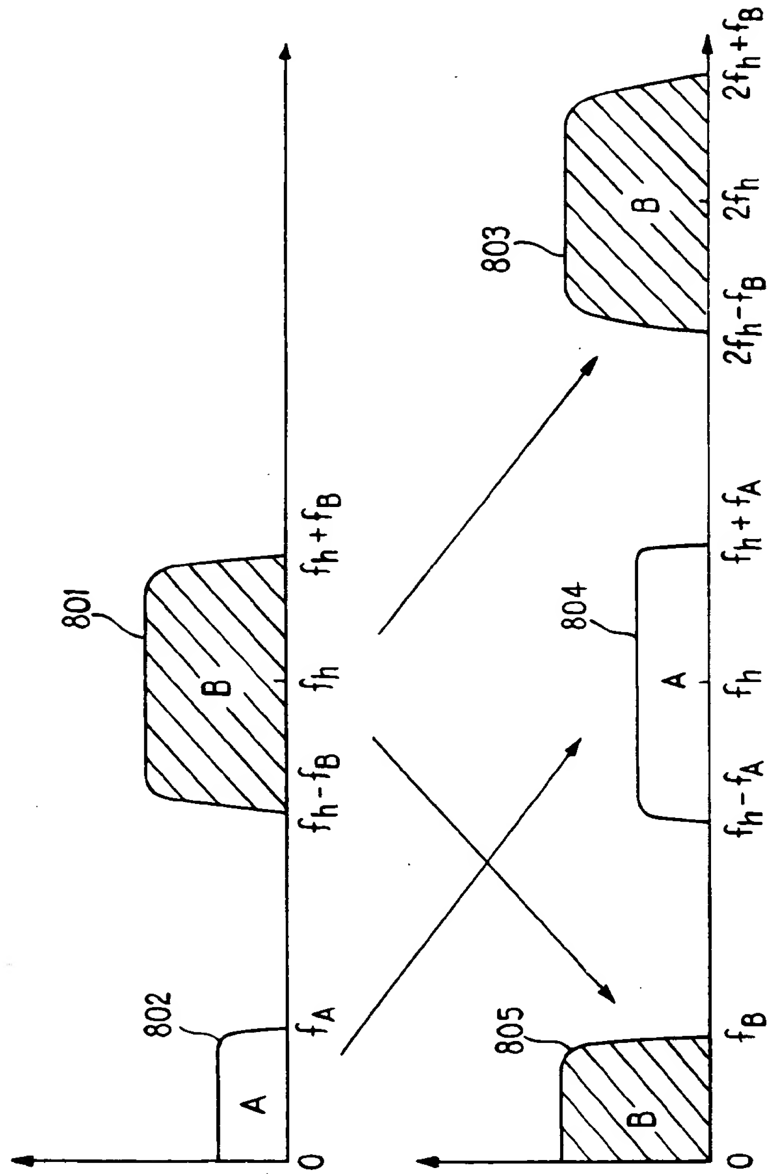

802
A
0
f_A
801
B
f_h-f_B
f_h
f_h+f_B
805
B
0
f_B
804
A
f_h-f_A
f_h
f_h+f_A
803
B
$2f_h-f_B$
$2f_h$
$2f_h+f_B$

FIG.8a

FIG.8b

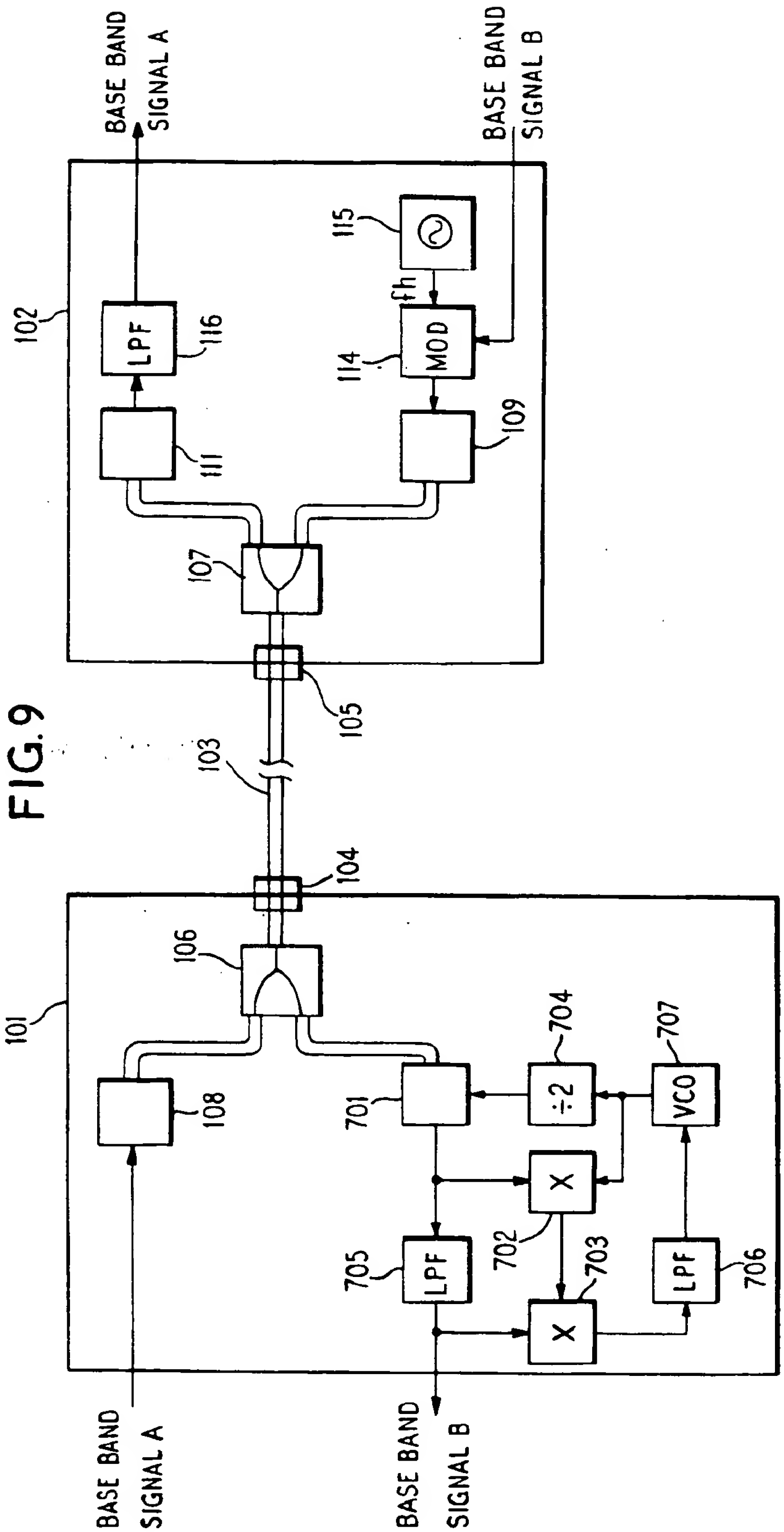

BASE BAND SIGNAL A
BASE BAND SIGNAL B
102
LPF
116
115
fh
MOD
114
111
109
107
105
103
104
101
106
108
701
÷2
704
VCO
707
X
702
703
LPF
705
LPF
706
X
BASE BAND SIGNAL A
BASE BAND SIGNAL B

FIG. 9